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PRIDE: Near-field VLBI observations for Planetary Probes

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Abstract

Planetary Radio Interferometry and Doppler Experiment (PRIDE) is a multi-purpose experimental technique aimed at enhancing the science return of planetary missions. It is based on, the near-field phase-referencing VLBI (Very Long Baseline Interferometry) and radial Doppler measurements. It has been developed initially by the Joint Institute for VLBI ERIC (JIVE) for tracking the ESA's Huygens Probe during its descent in the atmosphere of Titan in 2005 and from that point forward actualized for various planetary science missions. It was selected by ESA as one of the eleven experiments of the ESA's L-class JUpiter ICy moons Explorer mission (JUICE) mission, planned for launch in 2022.

1. Introduction

The essence of the PRIDE technique is in interleaving observations of the spacecraft radio signal and the signal of background natural celestial sources, generally quasars, enabling estimates of the lateral position of the spacecraft in the celestial reference frame [1] and Doppler-shift of the spacecraft's radio signal (radial range rate) [2, 3]. These estimates can be applied to a broad scope of research fields including atmosphere and precise celestial mechanics of planetary systems, geophysics and planetary dynamics and estimations of interplanetary plasma properties. PRIDE has been included as a part of the scientific suite on various ESA missions.

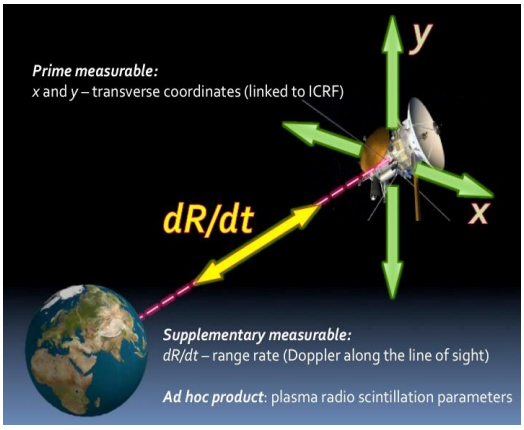

Figure 1: PRIDE Deliverables

1.1 Scientific Heritage

We introduce and present some of the experimental results accomplished recently in VLBI and Doppler measurements of the ESA's Venus EXpress (VEX) and Mars EXpress (MEX) missions [1, 2, 3]. PRIDE has been demonstrated in occultation experiments with Venus Express for determining the vertical density, pressure and temperature profiles of the Venus atmosphere [7] as well as ad hoc diagnostics of the interplanetary medium and detection of the Coronal Mass Ejection Event [6,8].

2. PRIDE-JUICE

PRIDE-JUICE will provide an enrichment of the JUICE science return achievable with minimum PRIDE-specific requirements to the onboard science payload [5]. It will address mission goals of JUICE that require exact determination of the lateral position

of spacecraft on the celestial sphere, in particular for improvement of the Jovian system ephemerides [4].

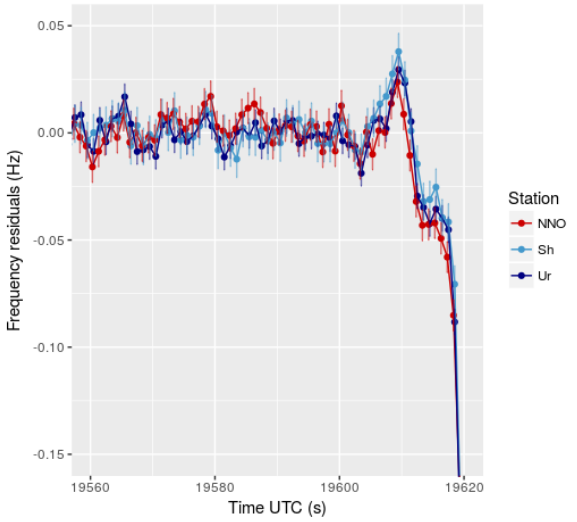

Figure 2: Frequency residuals of the spacecraft signal as it gets refracted by Venus' ionosphere and neutral atmosphere. This figure shows the comparison between the residuals found during ingress for Ur (Urumqi) and Sh (Shanghai) with respect of those of NNO, as provided by ESA's planetary science archive (PSA), for the 2012.04.27 session. The highest peak of positive frequency residuals corresponds to the main layer of the ionosphere. The immersion in the troposphere is marked by the change of sign in the frequency residuals at ~19610 s [7].

The PRIDE measurements can be used to investigate the Jovian atmosphere and physical properties by means of radio occultation observations [7,8]. The experiment will contribute to investigations of the interior structure of the moons can also be obtained from the joint investigation of topography and gravity field data. Also, although PRIDE could provide some support to gravity field determination using the Doppler data, the bulk of gravity science will be obtained from 3GM data.

A covariance analysis for a broad scope of the PRIDE measurable and Jovian system parameters have been performed in order to optimize the observation planning and the overall science impact of the JUICE mission [4].

PRIDE provides measurements of the spacecraft differential lateral position relative to the ICRF background extragalactic radio sources with the highest accuracy of 100-10 μas (1 sigma RMS) over integration time 60-1000 s. In addition to the JUICE mission objectives, PRIDE can also provide a backup support to mission operations in a form of rapid-response radio signal diagnostics.

We will also present some of the current & imminent PRIDE targets like LaRa (Lander Radio Science) on ExoMars mission. The PRIDE method described in this presentation exhibits its relevance and adaptability to any various space and planetary science missions.

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